Patent claims

1. A method for melting inorganic materials, glasses and/or glass-ceramics in a melting unit with cooled walls, in which material to be melted is fed to the melting unit and heated by supplying heating energy, wherein

- the temperature T_{eff} at which the energy consumption per unit weight of the material to be melted, given a suitably adapted throughput, is at a minimum is determined,
- the temperature of the melt in the melting unit is selected in such a way as to be in a range from T_{eff} - 20% to T_{eff} + 20%, and
- the throughput is selected in such a way as to be adapted to the required residence time.

2. The method as claimed in claim 1, wherein the temperature T_{eff} is given by

$$(1)\quad dE_{tot}/dT\Big|_{T=T_{eff}} = 0 = dE_N/dT\Big|_{T=T_{eff}} + dE_V/dT\Big|_{T=T_{eff}}$$

where E_N denotes the useful heat per unit weight of material to be melted and E_V denotes the energy loss per unit weight of material to be melted.

3. The method as claimed in claim 2, wherein the derivative of the useful heat per unit weight of material to be melted according to temperature is given by $dE_n/dT = c_p$, where c_p denotes the specific heat capacity of the melt.

4. The method as claimed in claims 2 and 3, wherein the

derivative of the energy loss per unit weight of melting material, E_V according to temperature is given by $dE_V/dT = k F_0 1/\rho \tau_0 e^{+E/T} + k T F_0 1/\rho \tau_0 (-E/T^2) e^{+E/T}$, where k denotes the total transfer of heat through the walls of the melting unit, $F_0 = F/V$ denotes the surface to volume ratio of the melt, ρ denotes the density, τ_0 denotes the required residence time at a reference temperature T_0, and E denotes a constant corresponding to a characteristic activation temperature.

5. The method as claimed in one of the preceding claims, wherein thermal energy is fed direct to the melt.

6. The method as claimed in claim 5, wherein the melt is additionally mixed in the melting unit.

7. The method as claimed in claim 6, wherein the melt is agitated using a stirrer and/or by bubbling.

8. The method as claimed in either of claims 6 and 7, wherein a convective flow is generated in the melt.

9. The method as claimed in claim 8, wherein a convective flow is produced by setting a viscosity of $< 10^3$ dPas, preferably of $< 10^2$ dPas, and a melt temperature difference between an inner region of the melt and an outer region of the melt of > 150 K, preferably > 250 K.

10. The method as claimed in claims 5 to 9, wherein the material to be melted is supplied in the form of batch which is placed onto the surface of the melt.

11. The method as claimed in claims 5 to 9, wherein material to be melted is stirred into the melt in the form of batch.

12. The method as claimed in claims 5 to 12, wherein batch is added in the form of pellets.

13. The method as claimed in one of the preceding claims, in which melting material is refined.

14. The method as claimed in claim 13, wherein a convective flow is produced in the melt.

15. The method as claimed in claim 14, wherein a convective flow is produced by setting a viscosity of $< 10^3$ dPas, preferably of $< 10^2$ dPas and a melt temperature difference between an inner region of the melt and an outer region of the melt of > 150 K, preferably > 250 K.

16. The method as claimed in claims 13 to 15, wherein molten material is introduced into a crucible from one side of the crucible at the melt bath surface and is discharged again on an opposite side at the melt bath surface.

17. The method as claimed in one of the preceding claims, wherein the material to be melted is refined using high-temperature refining agent.

18. The method as claimed in one of the preceding claims, wherein melting material is continuously fed to and removed from the melt.

19. The method as claimed in claims 1 to 12, wherein the temperature T_{eff} is determined for the melting-down of batch.

20. The method as claimed in claim 19, wherein the temperature T_{eff} is determined for a melt which is additionally mixed.

21. The method as claimed in claim 19, wherein the temperature T_{eff} is determined for a melt which has a viscosity of < 10^3 dPas, preferably of < 10^2 dPas and is melted in a unit at which a temperature difference in the melt between the inner region of the melt and the outer region of the melt is > 150 K, preferably > 250 K.

22. The method as claimed in claims 1 to 4 and 13 to 17, wherein the temperature T_{eff} is determined for the refining of the melt.

23. The method as claimed in claim 22, wherein the temperature T_{eff} is determined for a melt which has a viscosity of < 10^3 dPas, preferably of < 10^4 dPas and is melted in a unit at which a temperature difference in the melt between the inner region of the melt and the outer region of the melt is > 150 K, preferably > 250 K.

24. The method as claimed in claims 22 and 23, wherein the temperature T_{eff} is determined for a melt in which molten material is introduced into a crucible from one side of the crucible at the melt bath surface and is discharged again on the opposite side at the melt bath surface.

25. The method as claimed in claims 1 to 24, wherein thermal energy is fed direct to the melt.

26. The method as claimed in claim 25, wherein thermal energy is fed to the melt by direct conductive heating.

27. The method as claimed in claim 25, wherein thermal energy is fed to the melt by direct inductive heating.

28. The method as claimed in claims 1 to 27, wherein at least one region of the melt is heated to more than 1 700°C.

29. The method as claimed in one of the preceding claims, wherein the temperature of at least one region of the melt is selected to be less than or equal to a temperature at which the useful heat and the energy loss per unit weight of the material to be melted are equal.

30. The method as claimed in one of the preceding claims, wherein the adapting of the relative throughput of material to be melted to the required residence time in the melt comprises adapting the absolute quantitative throughput.

31. The method as claimed in one of the preceding claims, wherein the adapting of the relative throughput of material to be melted to the required residence time in the melt comprises adapting the melt volume or the dimensions of the unit.

32. The method as claimed in one of the preceding claims, in which the required residence time comprises the melt-down time.

33. The method as claimed in one of the preceding claims, in which the required residence time comprises the refining time.

34. An apparatus for melting inorganic materials, glasses and glass-ceramics, for carrying out the method as claimed in one of claims 1 to 33, which apparatus comprises

- a melting unit with cooled walls,
- a device for supplying material to be melted, and
- a device for the direct heating of a melt,

and which apparatus also includes

- a device for setting a temperature which is at least T_{eff} - 20% to T_{eff} + 20% in at least one region of the melt, the temperature T_{eff} being given by the temperature at which the energy consumption per unit weight of the material to be melted, with a throughput which is suitably adapted to the residence time required at a given temperature, is at a minimum, and
- a device for adapting the relative throughput of material to be melted to the required residence time in the melt.

35. The apparatus as claimed in claim 34, wherein the melting unit with cooled walls comprises a skull crucible.

36. The apparatus as claimed in claim 34 or 35, which includes a stirrer for agitating the melt.

37. The apparatus as claimed in one of claims 34 to 36, which includes at least one nozzle for introducing bubbling gas.

38. The apparatus as claimed in one of claims 34 to 37, wherein the device for the direct heating of the melt comprises a device for the conductive heating of the melt.

39. The apparatus as claimed in claim 38, wherein the device for the conductive heating of the melt comprises cooled electrodes.

40. The apparatus as claimed in claim 39, wherein the electrodes are inserted into cutouts in the cooled walls of the unit.

41. The apparatus as claimed in one of claims 34 to 40, wherein the device for the direct heating of the melt comprises a device for the inductive heating of the melt.

42. The apparatus as claimed in claim 41, wherein the device for the conductive heating of the melt comprises at least one induction coil.

43. The apparatus as claimed in one of claims 34 to 42, which includes a device for continuously supplying material to be melted.

44. The apparatus as claimed in one of claims 34 to 43, which includes a device for continuously removing molten material.

45. The apparatus as claimed in one of claims 34 to 44, wherein the cooled walls have a surface which reflects thermal radiation.

46. A glass producible by the method as claimed in one of claims 1 to 33.

47. The glass as claimed in claim 46, preferably produced by the method as claimed in one of claims 1 to 33, wherein the ratio of Sn^{2+} to Sn_T has a value of greater than 0.25, preferably greater than 0.35, particularly preferably greater than 0.45.

48. A glass product producible by the method as claimed in one of claims 1 to 33.

49. The glass product as claimed in claim 48, preferably produced by the method as claimed in one of claims 1 to 33, wherein the ratio of Sn^{2+} to Sn_T has a value of greater than

0.25, preferably greater than 0.35, particularly preferably greater than 0.45.